DATA ASSIMILATION AND COUPLING THE GLOBAL NRL MODEL WITH THE REGIONAL PRINCETON OCEAN MODEL

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LONG-TERM GOALS

Contribute to the development of the components of limited area, open-boundary, coastal Nowcast/forecast systems which will resolve the time and scales of the relevant ocean dynamics in shallow coastal environments.

OBJECTIVES

TASK 1. Improvement of the data assimilation capability of the NRL Layered Ocean Model in the framework of the Data Assimilation and Rapid Transition system of NRL;
TASK 2. Development of technology for coupling NRL's layered global model with regional coastal models.

APPROACH

TASK 1. The NRL data assimilation system includes (Carnes et. al., 1996): optimum interpolation of altimeter sea surface heights; statistical inference of the subsurface fields and nudging of this information into the model governing equations. In the project, the energy integrals derived from the model are used to constrain subsurface fields estimated using the statistical inference technique. In this case, the projection of surface information into subsurface fields is divided into two steps: the first guess of the nudging terms is obtained by the statistical inference technique; then, a simple variational problem is used to correct these terms in accordance with the current model dynamics. This approach combines the statistical and dynamical information and provides a continuous feedback from the model to the inference of subsurface fields. Consultations from Drs. Hurlburt and Walcraft and Mr. Rhodes of NRL are valuable contributions to the overall success of this task.
TASK 2. Under the grant N00014-95-1-0258, the methods and technology had been developed for coupling basin scale and limited area coastal models (Shulman and Lewis 1995, 1996). This technology is being extended and applied to couple the NRL layer model

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with the Pacific West Coast model which is under development at NRL. This research is performed in collaboration with Dr. D.S. Ko, Sverdrup Technology Inc., the key developer of the Pacific West Coast model, Dr. J. K. Lewis, Ocean Physics Research & Development and Mr. J.G. Mayer, Ph.D student of Scientific Computing Program of USM.

WORK COMPLETED

TASK 1 was the main effort of the first year of the project:

* Four variational problems have been developed in order to constrain the statistical inference of subsurface fields: (A) Minimization of the norm of the nudging terms; (B) Conservation of the kinetic energy of the model; (C) Conservation of the potential energy of the model; (D) Conservation of the potential vorticity.
* The solutions of these variational problems were incorporated into software of the NRL data assimilation system.
* Preliminary data assimilation experiments (identical twin experiments) were conducted with the reduced gravity and finite depth versions of a 1/8 degree the Sea of Japan version of the NRL layered model.
* Paper prepared and submitted to the Proceedings of 5th International Conference on Estuarine and Coastal Modeling.

RESULTS

The identical twin experiments have been performed in order to test the proposed approach (Shulman and Smedstad, 1997). The 1/8° 4-layer finite depth the Sea of Japan version of the NRL model was spun up with climatological wind stresses, until equilibrium. The model was then forced with ECMWF daily winds for the period 1981 through 1994. The year 1982 was chosen to represent the real ocean in order to provide us with the "observed" sea surface height (SSH) and pressure distributions in the model layers. The SSH along Topex/Poseidon tracks were extracted from the model solution and assimilated into the model. The initial conditions for the assimilation experiments were taken to be the model field from the 5th day of 1991 from the ECMWF integration. The comparisons between the different data assimilation schemes were made after one year of assimilation at the 3 rd day of 1992.

Five different experiments were performed. In Case 0 the model was integrated without assimilating any observations, Case 1 used the optimization problem (A) (see section "Work Completed" of the report). In Case 2 the optimization (A) together with the problem (B) is used. Case 3 used the optimization problem (A) with the problems (B) and (C) In Case 4 the optimization problem (A) together with the optimization problem (D) is used.

The results of experiments are shown in Table 1. Where ζ_1 and ζ_2 are the maximum and minimum of the difference between the observed and model predicted SSH, and δRMS_k ;k=1; 4 represent the relative skill of the model in prediction of layer pressures and are the percentages of the root-mean-square (rms) error increase (positive) or decrease (negative) relative to the Case 1 run (optimization problem (A)).

Table 1

Name	Assimilation Method	ζ_1(cm)	ζ_2(cm)	δRMS_1	δRMS_2	δRMS_3	δRMS_4
Case 0	No assimilation	-11.0	13.1	200	260	136	5.6
Case 1	Optimization A	-5.9	5.9	---	---	---	---
Case 2	Optimization A&B	-3.9	4.3	-21.3	-11.2	-3.0	-5.3
Case 3	Optimization A,B&C	-3.7	3.6	-20.0	-9.0	-0.7	32.8
Case 4	Optimization A&D	-4.7	4.0	-8.2	-1.0	-1.8	0.0

The use of the optimization problem A produced a significant improvement in prediction of SSH and the layer pressures in comparison to the run without assimilation (Table 1). Combinations of problem A with the problems (B), (C), or (D) provided an improvement in the predictions for the top layers of the model (see Table 1), but a smaller improvement for the bottom layer. Results show that in all cases of assimilation of SSH there is a weak influence on bottom layer dynamics. This is probably due to the use of the statistical inference technique to estimate the changes in bottom layer pressure; also, the 1/8 model does not have enough resolution for realistic predictions in the area of the Sea of Japan (Hogan and Hurlburt, 1997). Fig.1 shows the observed and the model predicted SSH in the Case 0 (no assimilation) and the predicted SSH in the Case 3. As can be seen, the assimilated field is close to the "observed" field shown in Fig.1. Further experiments with the real data (Topex/Poseidon) will be conducted.

IMPACT/APPLICATIONS

Development of the oceanic prediction system is under way at the Naval Research Laboratory for use by the NAVOCEANO and Fleet Numerical Meteorology and Oceanography Center (FNMOC). This project is a contribution (TASK 1) to the improvement of the data assimilation capability of the system in inferring subsurface fields from surface information and tuning nudging parameters in order to reach the required prediction skill of the system.

Boundary conditions for limited area coastal models planned for operations at FNMOC and NAVOCEANO will be provided by the system. The development of technology for coupling the NRL system with the coastal models (TASK2) enhances the Navy's capabilities in the development of coastal nowcast/forecast models and will provide new possibilities for operational environmental forecasting.

TRANSITIONS

Developed techniques and software have being incorporated into the latest version of the NRL data assimilation system, which will be transitioned to the FNMOC and NAVOCEANO.

RELATED PROJECTS

6.2 Basin Scale Prediction System project, Data Assimilation and Rapid Transition (DART) and Large-Scale Modeling tasks (Naval Ocean Modeling and Prediction program, ONR) "Assimilation of Observations into Coastal and Nearshore Circulation Models", (Naval Ocean Modeling and Prediction program, ONR).

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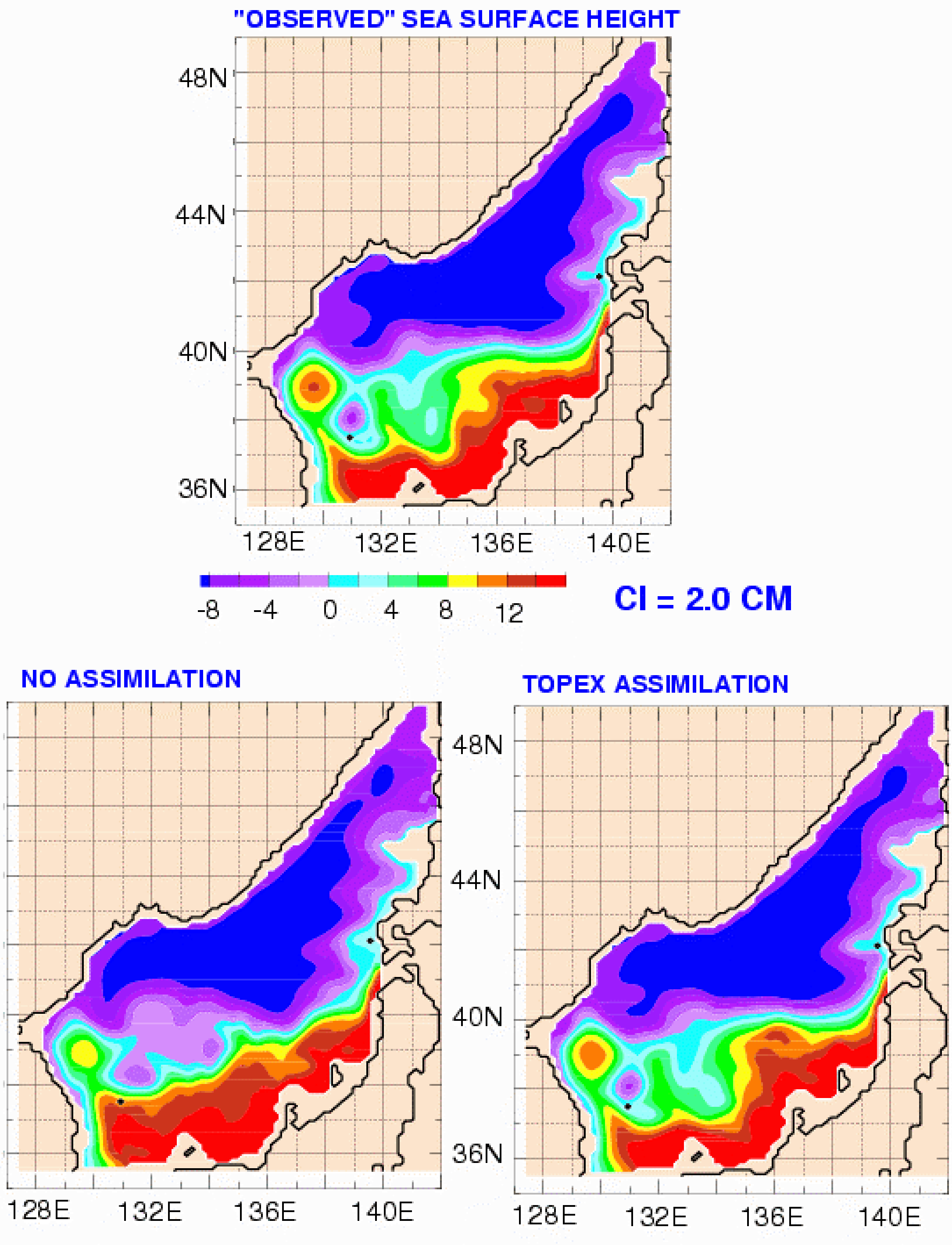
"OBSERVED" SEA SURFACE HEIGHT
48N
44N
40N
36N
128E
132E
136E
140E
-8
-4
0
4
8
12
CI = 2.0 CM
NO ASSIMILATION
TOPEX ASSIMILATION

FIGURE 1